XI. *The Human Electrocardiogram: a Preliminary Investigation of Young Male Adults, to form a Basis for Pathological Study.*

By THOMAS LEWIS* *and* M. D. D. GILDER.

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(From the Cardiographic Department, University College Hospital Medical School, London.)

[PLATES 19 AND 20.]

The adoption of the galvanometer and its employment for clinical purposes dates from the introduction of the newly modelled instrument or string galvanometer by EINTHOVEN.

The string galvanometer has proved an efficient instrument in deciphering all forms of irregularity of the ventricle, and has given clear interpretations of all derangements of the heart in which there is disorder in the sequence of contraction in its chambers. This new chapter of clinical medicine is rapidly closing, but while it has been written, a number of isolated observations have been placed on record, from which it is clear that the instrument may be employed for a further purpose. It is probable that it will give information of much value where the action of the heart, as a whole, is perfectly regular, and where the contraction, originating at the normal site of impulse formation, namely, the sino-auricular node, progresses at normal rates through the heart and along definite and recognised channels. Thus, it is known that in certain instances of cardiac enlargement some of the electric variations portrayed in the curves are exaggerated, decreased, or inverted, as compared to the normal and to each other. But it is evident that little progress can be made in the study of this subject until we have full knowledge of the normal electrocardiogram, and especially of the limits which may be reached by its several peaks and depressions in healthy subjects. As an initial step towards this end we have examined the curves of a large number of healthy young adults.

METHODS ADOPTED.

For the purposes of this investigation we have taken the material which has been at hand, namely, medical students of healthy aspect, whose ages ranged from 18 to 35 years. We wished to collect the electrocardiograms of 50 or more such subjects, and in taking an actual total of 59 subjects,† we have rejected seven. The reasons for

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† The actual number of observations, described in this communication, does not represent the whole of the material studied. We decided that it was desirable for the purposes of the investigation to commence with a clean slate, using the experience of the past simply as a guide to our work.

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the rejection of these seven subjects will be fully stated when the normal curves have been considered.

The records have been taken by means of Edelmann's pattern of Einthoven's string galvanometer (No. 1500 in Edelmann's Catalogue). The magnet of this galvanometer is an electromagnet, and the string employed in the present work has been a platinum fibre having a resistance of 11,600 ohms. The routine adopted in the examination of any given subject is that of EINTHOVEN, and is described in his paper in the 'Archives internationales de Physiologie,' 1906, vol. 4, p. 132. The curves are taken from three leads—right arm to left arm, right arm to left leg, and left arm to left leg, henceforth termed leads *I*, *II*, and *III* respectively.

Estimation of Resistance.

The subjects sit in easy and uniform positions,* and the leading-off electrodes are attached to the three limbs, any pair of which may be selected at the main switch board. The resistances of the separate leads are estimated by means of a telephone and Wheatstone's bridge. The instrument employed for this purpose gives readings to within 50 ohms of the resistance tested,† an approximation which is more than sufficiently accurate for our purposes. The actual resistances, as measured, have lain between 300 and 900 ohms.

Standardisation of the Instrument.

The resistance being ascertained, a corresponding quantity is thrown into the galvanometric circuit. In taking some of the earlier records, we maintained a uniform resistance of 21,600 ohms in the circuit, measuring the resistance of the subject in each instance and adding to it the quantity necessary to bring the total to 21,600 ohms. The total resistance was established by the string of 11,600 ohms and by an added resistance of 10,000 ohms. This method was adopted because it necessitated fewer tests of the excursion of the string, when a current of definite strength was passed through it, and several subjects might be observed in rapid sequence without further alteration of the string tension. But later we found that so large an internal resistance reduces the sensitivity of our instrument to a point which is inconvenient for all observations, and we consequently discarded the method in favour of standardisation on each occasion with a resistance equivalent to that of the patient alone in circuit with the string.

Eventually we instituted a careful comparison of the two methods, namely, standardisation of the string with (1) an added resistance of 10,000 ohms, including

* We have made a number of observations upon the effect of posture, to determine the uniformity of position which it is necessary to maintain in order to secure uniformity in the curves. Small deviations from a given posture are without significance.

† This approximation is safe because of the high total resistance, usually more than 12,000 ohms, in the galvanometric circuit.

the resistance of the patient, and with (2) an added resistance equivalent to the resistance of the subject. This comparison has yielded results of value, which will be referred to in more detail in succeeding paragraphs.

The instrument is standardised by throwing an accurately measured potential of 3 millivolts, from a Weston normal cell, into the galvanometric circuit, and by altering the tension of the string until a deviation of exactly 3 cm. is obtained. The excursion obtained by $\frac{1}{1000}$ volt, namely, 1 cm., is checked immediately after the electrocardiogram is taken, the record usually lying on the same plate (figs. 1, 12, and 14). All the measurements of curves referred to in the present communication have been made from the horizontal lines which are ruled photographically upon the plates at intervals of 1 mm. These lines are seen in the figures and for the convenience of measurement the ruling is so arranged that each fifth line is somewhat thicker than the remainder.

Estimation of the Deflection Time of the String.

It is very essential, if the curves are to accurately represent the variations in the strength of the current flowing through the string, that the deflection time of the string should be accurately ascertained and graduated according to the rate of change in the strength of the currents tested. For human electrocardiographic work, SAMOJLOFF* states that the deflection time should not exceed 0·03 sec. From our past experience we know that deflection times of greater magnitude certainly produce distortion of the curves, distortion which is always present, when the time amounts to 0·06 sec. or less. But it was thought desirable that the limit of safety should be more accurately defined.

The deflection time of the string varies with the amplitude of excursion; the greater the amplitude, the longer the time, though the change is not proportional. In speaking of a deflection time of 0·03 or 0·06 sec., a deflection time of a string shadow which passes over a distance of 1 cm. is understood. Now, if the exact outline of a normal electrocardiogram is known, the safe maximal limit for the deflection time, for the particular subject and lead, may be estimated by measuring the time duration of the quickest deflection in the curve itself. Thus, in fig. 1*A*, the line joining the apices of *R* and *S* is the most vertical in the curve. The actual duration of the swing from the point of *R* to the point of *S* is approximately 0·023 sec. Consequently the maximal limit of the deflection time which it is safe to employ in obtaining a perfect representation of the current changes in this instance should be 0·023 sec.; for the total excursion from the top of *R* to the bottom of *S* is 10·5 mm., or approximately 1 cm. And the adoption of any deflection time of lesser magnitude than 0·023 sec.† should yield a curve which is identical with fig. 1*A* in measurements and general outline. That this is actually the case may be seen from the remaining

* "Elektrokardiogramme," 'Sammlung anatomischer und physiologischer Vorträge und Aufsätze,' Gaupp and Nagel, Jena, 1909.

† Always providing that the limit of overtightness of the string is not reached.

TABLE I.

	P.	*Q.*	*R.*	*S.*	*T.*	Deflection times.
						sec.
Fig. 1*A*	1·0	0	6·5	4·0	4·0	0·013
Fig. 1*B*	1·0	0	6·5	4·0	4·0	0·023
Fig. 1*C*	1·0	0	6·0	3·0	4·0	0·028
Fig. 1*D*	1·0	0	5·5	3·0	4·5	0·045
Fig. 1*E*	0·7	0	4·7	1·7	4·5	0·060
Fig. 1*F*	0·7	0	4·0	1·3	4·5	0·070

A tabulated statement of the measurements of the curves in figs. 1 *A–F*.

curves of the same figure. The deflection times corresponding to figs. 1*A* and 1*B* are 0·013 and 0·023 sec. respectively. The corresponding curves are alike in every respect, but as soon as the limit of safety, in this instance 0·023 sec., is passed, alterations are noticed in the curves: the first change is in the amplitude of the depression *S*. Thus in fig. 1*C*, taken when the string gave a deflection time of 0·028 sec., or $\frac{5}{1000}$ sec. beyond the calculated limit of safety, a shortening of *S* from 4 mm. to 3 mm. occurs, while, with the exception of a slighter reduction in *R*, the remainder of the summits practically retain their original measurements and outlines.

To complete the illustration, we publish three further curves in which deflection times of 0·045, 0·060, and 0·070 sec. were employed. The curves show more and more distortion. *R* and *S* gradually become reduced in amplitude, as they are traced from above downward through the series. These are the peaks which suffer most. *P* is slightly reduced in amplitude in the last two curves, figs. 1*E* and 1*F*, while *T* shows a slight but appreciable increase in figs. 1*D*, 1*E*, and 1*F*.*

In our observations upon students, we have adopted deflection times which we know from experience to be at or near the maximal limit of safety, on a number of occasions, and we have compared the curves thus obtained with the curves given while using deflection times of lesser magnitude. In making such observations two complete photographs are taken in quick succession; each consists of curves from the three leads, and the measurements in the two photographs are subsequently compared. The comparisons will be found in Table III, wherever two curves from the same subject are charted under one date.

To illustrate the curves we publish figs. 12 and 14, from a subject in whom the desired deflection time is small; they were taken within a few minutes of each other. The deflection time for fig. 12 is 0·012 sec., and for fig. 14, 0·022 sec. The general outline of the curves from the three leads is well maintained in the two photographs. The differences in measurements are minute, but are in many ways characteristic of the slight distortion of curves which occurs at or about the deflection times

* The illustration is but an example of a number of serial observations.

TABLE II.

No.	Initials.	Deflection times.	Losses.	Gains.
1	C. E. S.	0·016 0·021	R^2 from 15 to 14	
7	C. E. A. G.	0·016 0·025	S^2 from 3·5 to 3 R^3 from 12 to 11	T^3 from 1 to 1·3.
11	J. M. E.	0·018 0·028		No differences.
12	H. C. G. P.	0·013 0·021		R^2 from 12 to 12·5. T^1 from 2·5 to 3·0.
14	G. G. A.	0·012 0·022	S^1 from 3·5 to 3 S^2 from 1 to 0 S^3 from 1 to 0·5 R^2 from 13 to 12 R^3 from 11 to 10	R^1 from 3·5 to 4. T^1 from 1·3 to 2. T^2 from 3·0 to 3·5.
20	L. B. C. T.	0·013 0·016		No differences.
27	A. P.	0·016 0·023	S^1 from 1 to trace S^2 from 1·5 to 0·5 S^3 from 1 to 0. R^3 from 5 to 3·5 Q^2 from 1 to 0·7 T^3 from 0·5 to trace	R^2 from 8·5 to 9·5. Q^3 from 1 to 1·5. T^1 from 2 to 2·5. T^2 from 2·5 to 3·5.
29	C. McI.	0·018 0·025	S^2 from 2 to 1 S^3 from 2 to 1·3	R^1 from 4·5 to 5·0. T^1 from 1·0 to 1·5.
42	H. D.	0·010 0·020	R^2 from 9 to 8·5	
48	E. B. J.	0·013 0·021		P^2 from 0·7 to 1. Q^2 from 0·5 to 1. R^2 from 8·5 to 9. There were also gains in the bracketed Q, R, S deflection of leads *III*.
51	R. H. L.	0·016 0·020	R^1 from 5·5 to 5 S^2 from 4·0 to 3·5 S^3 from 4 to 3 T^1 from 2·7 to 2·3 T^2 from 2·5 to 2	
59	P. V. E.	0·013 0·023	S^2 from 2·0 to 1·5 T^2 from 3·5 to 3	

A table showing the alteration in the amplitude of the summits and depressions, when deflection times of 0·010–0·018 sec. are replaced by deflection times of 0·016–0·028 sec. A number of the gains and losses, especially those which fall upon Q and R, are no more than are to be accounted for by natural variation in the amplitudes of these deflections from time to time.

0·020–0·025 sec. For example S^1 is reduced from 3·5 mm. to 3 mm.; S^2 is reduced from 1 mm. to 0 mm.*; S^3 is reduced from 1 mm. to 0·5 mm. R^3 is also reduced from 11 mm. to 10 mm., and R^2 from 13 mm. to 12 mm. On the other hand R^1 is increased from 3·5 mm. to 4 mm.,† T^1 gains from 1·3 mm. to 2 mm., and T^2 from 3 mm. to 3·5 mm.

The comparison has been instituted in 12 instances, using smaller deflection times, which varied from 0·010 sec. to 0·018 sec., and longer deflection times varying from 0·016 sec. to 0·028 sec. The quantities of loss or gain in the summit R and in the depression S must be surveyed in the whole series, for the variation in the size of these peaks from beat to beat introduces a slight error into many such calculations. The losses and gains in the whole series are given in the accompanying table (Table II). It will be seen that the gains, in so far as they affect R and Q, are small in number and inappreciable in extent. They fall upon Q^3, R^1, and R^2.‡ There is a frequent slight gain in T, especially in T^1. S shows no gain. The losses are numerous though inappreciable in extent. The most conspicuous losses are in S^2, S^3, R^3, S^1, and R^2, in this order.

The modifications produced in the electrocardiogram, when deflection times of magnitudes lying in the neighbourhood of the maximal limit of safety are employed, accord well with our general experience of electrocardiograms, and with our knowledge of the rapidity with which their summits and depressions are inscribed. The most important feature is the occasional abolition of S in lead *II* and in lead *III*; the remaining changes are insignificant and almost negligible.

It is evident that within certain limits different deflection times are suitable for individual subjects and individual leads, and it is also evident that a given deflection time may affect one curve in one way, another curve in another way. But, speaking of the aggregate, it may be assumed that, if maximal deflection times of between 0·020 sec. and 0·025 sec. are employed, curves obtained from young and normal subjects will be affected only to a trifling extent, and that if the smaller value is adopted any distortion which occurs will be so slight as to be negligible.

The Electrocardiograms of 59 Subjects.

The accompanying tables (Tables III and IV) are arranged in columns which require brief explanation. We have inserted columns for the date of observation, the age of the subject, his height and weight, and the heart rate as calculated from the actual curves. In an end column, under the heading "Remarks," we have inserted a list of infectious diseases from which the subjects of the investigation have suffered.

* In fig. 12 *II*, S varies from 1 to 2 mm., but the average measurement is about 1 mm.

† These small changes in R are probably largely accidental.

‡ These gains, like many of the losses in R and S, are probably accidental and dependent upon natural and slight variation in the heights of peaks from time to time.

The remaining columns refer to the size of the heart, the character of the heart sounds, and finally to measurements obtained from the curves.

The Size of the Heart.

The size of the heart has been estimated by percussion of its deep limits. We are aware of many possible sources of error in taking the maximal limits of dulness, as measured from the mid-sternal line by percussion.* In taking these subjective readings, the personal factor is an important one, for few people percuss the heart in a precisely similar fashion, or recognise the same limits of dulness in health; the percussion readings have consequently been taken by one of us and have been compared to a standard obtained as a result of his own individual experience in this respect. In accordance with this standard the maximal limits of normal dulness have been arbitrarily fixed at 2·5 inches on the right side and 4·5 inches on the left side, measuring always from the mid-sternal line.

Measurements of Curves.

So far as possible the summits and depressions of the electrocardiographic curves have been measured from a base line, lying at the level of the commencement of the summit *P*. This base is very serviceable for the measurement of *P*, *R*, *S*, *T*, and *U*. *Q*, also, often starts from it; but where, as is sometimes the case, the curve following *P* dips below the horizontal, *Q* starts at this somewhat lower level (fig. 9), and the measurement has then been taken from the point of its commencement.

We have constructed two additional columns, in one of which the *P–R* interval is stated; the *P–R* interval is tabulated for lead *II* only. In the other column the deflection time of the string, for an excursion of 1 cm., and in response to a standard current of $\frac{1}{1000}$ volt, is given. Certain of these last-named values are marked approximate; they are deflection times belonging to curves which were taken in batches, a single deviation time being calculated and checked for a batch of observations.

The asterisks in the table signify that the peak in question was split. In the case of the *P* summit the division into two parts was usually at the apex of the peak. Where *R* or *S* have shown bifurcation the splitting has been in its opening phase, or at its centre.

Where two quantities are given for the height of a *T* summit, two distinct variations have been present, and are represented in the table in the correct order, the signs + (plus) and − (minus) are used to indicate upward and downward variations, respectively.

Where there has been variation in the size of a peak from cycle to cycle, an average reading is given.

* Measurement of the heart in the living subject, whatever the means adopted, has a comparative rather than an actual value.

TABLE

No.	Initials.	Date.	Age.	Height.	Weight.	Heart rate.	Heart limits.		Heart sounds.	Lead *I*.					
							Right.	Left.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.
				ft. in.	st. lb.										
1	C. E. S.	8.12.11	24	5 6	11 0	82	1·5	4·25	N.	0·3	Tr.	3·0	0·5	2·0	0
		11.1.12				82				0·3	0·5	3·0	0·5	2·5	0
		11.1.12				82				0·3	0·5	3·0	0·5	2·5	0
2	D. N. S. S.	14.12.11	24	5 11·5	10 5	90	1·5	3·6	N.	0·3	0	3·0	1·5	1·0	Tr.
3	A. C. S. C.	14.12.11	25	5 10	9 0	56	2·25	4·0	N.	0·7	0·5	3·5	1·0	2·0	Tr.
		19.1.12				72				0·7	0·5	3·5	1·5	2·0	Tr.
4	A. R. McG.	12.12.11	24	5 11	12 0	82	2·25	4·0	N.	0·5	0	3·0	3·0	1·0	Tr.
5	F. C. S.	8.12.11	29	5 8·5	12 0	60	1·25	3·75	Cardio-pulm. murmur	0·3	0	2·0	1·0	1·5	Tr.
6	C. W. M.	31.10.11	26	5 5·7	8 0	64	1·75	4·0	N.	0·5	0·5	6·0	2·0	2·5	0
7	C. E. A. G.	8.12.11	24	5 11	10 12	82	2·12	4·0	N.	0·5	0·3	4·0	4·0	2·0	?
		12.1.12				90				0·5	0·3	3·5	4·0	1·5	?
		12.1.12				82				0·5	?	3·5	4·0	1·5	?
8	J. E. T. J.	14.12.11	24	5 9·5	10 3	72	2·0	3·62	N.	0·3	0	3·0	5·5	−1·0 +0·5	Tr.
9	F. H. R.	20.1.12	22	5 10·5	10 10	69	2·0	3·6	N.	1·0	0	6·0	4·0	3·5	Tr.
		22.1.12				75				1·0	0	5·5	4·0	3·0	Tr.
		23.1.12				82				1·0	0	6·0	4·0	4·0	Tr.
10	D. P. P.	5.12.11	25	5 8	8 10	80	2·5	4·5	N.	0·5	Tr.	2·0*	5·0	1·5	Tr.
11	J. M. E.	8.12.11	21	5 11	11 13	56	1·75	3·75	N.	0·5	0	5·0	2·5	1·5	?
		12.1.12				59				0·5	0	5·0	2·5	1·5	?
		12.1.12				60				0·5	0	5·0	2·5	1·5	?
12	H. C. P.	8.12.11	26	6 3	14 0	90	2·0	4·25	N.	0·5	0	3·0	2·3	3·0	0
		12.1.12				72				0·5	0	2·5	2·3	3·0	0
		12.1.12				69				0·5	0	2·5	2·3	2·5	0
13	H. W. H.	12.12.11	23	5 10	10 7	75	2·0	3·25	N.	0·5	0·3	3·5	2·5	1·5	Tr.
14	G. G. A.	30.11.11	27	5 8	11 5	62	2·0	3·75	N.	0·7	0	4·5	2·5	3·3	0
		15.12.11				66				0·7	0	5·0	3·5	+2·3 −0·5	0
		15.1.12				60				0·7	0	4·0	3·0	+2·0 −0·5	0
		15.1.12				72				0·7	0	3·5	3·5	+1·3 −0·5	0
15	F. S. F. B.	30.10.11	28	5 11·7	11 0	60	2·0	4·25	N.	0·5	0	5·5	4·0	2·5	0
		17.1.12				66				0·5	0	5·0	3·5	1·5	0
16	T. L.	29.9.09	30	5 8·5	10 7	74	2·0	4·0	N.	1·0	0	2·0*	3·0	3·0	Tr.
		12.1.12				90				1·0	0	1·5*	3·0	1·7	Tr.
17	J. W.	5.12.11	24	5 11·5	10 0	54	1·5	4·25	N.	0·5	0·2	3·5	3·5	4·0	Tr.
18	A. D. E. B.	12.12.11	25	5 8·2	10 0	78	2·0	4·0	N.	0·5	0	4·5	4·0	3·0	0
19	L. L.	4.12.11	23	5 11	10 1	94	1·75	3·5	N.	Tr.	Tr.	2·5	1·0	1·5	0

† α = measles; β = mumps; γ = chicken-pox; δ = whooping cough;

III.

Lead *II*.						*P–R* interval.	Lead *III*.						Deflection time.	Remarks.†
P.	*Q*.	*R*.	*S*.	*T*.	*U*.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.		
1·0	2·5	12·5	4·0	2·5	Tr.	0·15	0·7	2·5	12·0	3·0	1·0	0	0·023 ap.	α, β, γ.
1·3	2·5	14·0	4·5	2·7	Tr.	0·16	1·0	2·5	13·5	3·0	1·0	0	0·021	
1·3	2·5	15·0	4·5	2·7	Tr.	0·16	1·0	2·5	13·5	3·0	1·0	0	0·016	
1·0	1·0	13·0	3·0	3·0	0·3	0·15	1·0	1·0	10·5	3·0	2·0	Tr.	0·013 ap.	α, γ, δ, rheumatic pains.
1·0*	Tr.	11·0	4·0	5·0	0·8	0·16	0·7*	1·0	8·0	4·0	3·0	0·3	0·013	α, β, ε.
1·0*	Tr.	11·0	4·0	4·5	0·7	0·15	0·7*	1·0	8·0	3·5	2·0	0·3	0·014	
1·0	1·0	13·0	4·0	1·5	Tr.	0·16	0·5	1·0	7·0	1·7	−0·5 +0·5	?	0·013	α, β, γ, δ, η, chronic sore throat.
1·0	0	6·0	3·3	+2·0 −0·5	Tr.	0·13	0·5	0	5·0	2·0	1·0	Tr.	0·023 ap.	α, ζ.
1·7*	1·0	13·0	4·0	3·5	0	0·15	1·5*	1·0	10·0	3·5	1·7	0	0·016 ap.	α, sore throat.
1·0*	0·5	11·0	3·0	2·0	Tr.	0·15	0·7	1·0	9·0	1·3	1·0	Tr.	0·023 ap.	α, γ, δ, pneumonia.
1·0*	0·7	12·0	3·0	2·0	Tr.	0·15	0·7	1·0	11·0	1·3	1·0	Tr.	0·025	
1·0*	0·7	12·0	3·5	2·0	Tr.	0·15	0·7	1·0	12·0	1·3	1·3	Tr.	0·016	
0·7	0·3	8·0	3·0	+1·0 −1·0	Tr.	0·13	0·5	0·5	7·5	2·0	−0·3 +1·0	?	0·013 ap.	α, δ, ε.
1·3	1·0	10·0	2·0	3·0	Tr.	0·13	0·3	1·5	10·0	0	−1·0	0	0·015 ap.	α, γ, δ, ε.
1·7	1·0	10·0	2·0	3·0	Tr.	0·13	0·3	1·5	11·0	0	−0·5 +0·5	0	0·012	
1·3	1·0	11·0	2·0	3·0	Tr.	0·13	0·3	1·5	10·5	0	−1·0 +0·5	0	0·013	
1·0	0·5	7·0	1·0	1·0	Tr.	0·15	1·0	1·5	8·5	0·5	−1·0	?	0·023 ap.	η, bronchitis.
0·7	1·0	12·0	2·0	2·0	?	0·16	0·5	0·5	9·5*	1·0	0·5	?	0·023 ap.	α, appendicitis.
0·7	Tr.	13·0	2·5	2·0	?	0·16	0·5	0·5	10·5*	1·5	0·5	?	0·028	
0·7	Tr.	13·0	2·5	2·0	?	0·16	0·5	0·5	10·5*	1·5	0·5	?	0·018	
1·5*	1·3	12·5	2·0	2·7	Tr.	0·16	1·0	1·3	10·0	1·0	0·5	?	0·023 ap.	α, mother had rheumatic fever, she has rheumatoid arthritis and double mitral disease.
1·5*	1·3	12·5	2·0	3·0	Tr.	0·16	1·0	1·3	10·0	1·0	1·0	?	0·021	
1·5*	1·3	12·0	2·0	3·0 ap.	?	0·16	1·0	1·3	10·0	1·0	1·0	?	0·013	
0·7	1·5	15·0	1·0	2·0	Tr.	0·13	0·3	1·0	10·5	0	0·5	?	0·013 ap.	α, β, δ, ε.
1·0	1·0	13·0	0	4·5	Tr.	0·18	0·7	1·0	10·0	0	0·2	0	0·023 ap.	α, β, γ, septic throat two years ago.
1·3	1·0	14·0	1·0	+3·0 −0·5	0	0·19	0·7	1·0	11·0	0·5	1·3	?	0·012	
1·0	1·0	12·0	0	+3·5 −0·5	Tr.	0·16	0·7	1·0	10·0	0·5	1·5	?	0·022	
1·0	1·0	13·0	1·0	+3·0 −0·5	0	0·18	0·7	1·0	11·0	1·0	1·5	?	0·012	
1·0*	0·3	12·0	0	4·0	Tr.	0·16	0·7*	0·5	9·5	0	1·5	0	0·016 ap.	
1·0*	0·3	12·0	Tr.	3·0	Tr.	0·16	0·7*	0·5	9·5	0	1·5	0	0·011	
1·7	0·5	10·5	3·5	2·5	Tr.	0·15	1·5	1·0	8·5	2·5	1·0	0	0·016 0·016	α, δ, sore throat. First curve taken at Leyden by Prof. Einthoven.
1·7	2·0	16·0	1·5	5·0	Tr.	0·18	1·5	2·0	14·0	0	1·5	Tr.	0·023 ap.	α, γ.
1·5	1·0	13·0	0	2·0	?	0·15	0·5	2·0	12·0	0	1·0	?	0·013 ap.	α (twice).
1·7	1·0	12·0	1·0	2·0	Tr.	0·16	1·5	2·0	9·5	0·5	1·5	Tr.	0·023 ap.	β, ζ.

ε = influenza; ζ = scarlet fever; η = diphtheria; * = split.

TABLE

No.	Initials.	Date.	Age.	Height.	Weight.	Heart rate.	Heart limits.		Heart sounds.	Lead *I*.					
							Right.	Left.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.
				ft. in.	st. lb.										
20	L. B. T.	8.12 11	29	5 11·5	11 0	106	2·0	4·2	N.	0·3	Tr.	2·5	2·0	1·0	Tr.
		9.1.12				95				0·3	Tr.	2·5	2·0	1·5	Tr.
		9.1.12				97				0·3	Tr.	2·5	2·0	1·5	Tr.
21	P. M. M.	8.12.11	34	5 5·5	9 7	92	2·0	3·5	N.	0·5	0	2·5	1·5	2·0	0
		8.1.12				108				Tr.	0	2·0	2·0	1·0	0
22	W. B. G.	8.12.11	22	5 7	9 7	90	2·0	4·5	N.	Tr.	0	2·0	1·5	1·0	0
23	H. N.	11.12.11	28	5 6·2	8 8	72	2·0	3·5	N.	0·5	0	3·5*	0	1·5	Tr.
24	M. D. D. G.	31.10.11	29	5 6·5	9 5	88	2·0	4·5	N.	Tr.	Tr.	6·5	1·0	1·0	Tr.
		8.1.12				109				Tr.	Tr.	6·0	1·0	1·0	Tr.
		19.1.12				95				Tr.	Tr.	5·5	1·0	1·0	Tr.
		22.1.12				95				Tr.	Tr.	5·5	1·5	1·0	Tr.
25	T. H. W. I.	12.12.11	31	5 7	10 0	90	1·5	3·25	N.	Tr.	0·5	4·0	1·5	0·7	0
26	M. B. C.	5.12.11	30	5 4	8 5	106	2·12	3·5	N.	0·7*	0·5	5·5	1·5	2·5	0
		8.1.12				92				0·5*	1·0	6·5	1·5	2·5	0
		11.1.12				80				0·7*	0·5	6·0	1·5	3·0	0
27	A. P.	8.12.11	25	5 8·7	11 0	75	2·0	4·0	N.	0·5	Tr.	4·0	Tr.	2·0	0
		9.1.12				60				0·5	Tr.	4·0	Tr.	2·5	Tr.
		9.1.12				66				0·5	Tr.	4·0	1·0	2·0	Tr.
28	H. M. D.	31.10.11	32	5 10	10 11	100	1·25	3·5	N.	0·5	0·5	5·0	0·5	1·0	0
29	C. McI.	12.1.12	27	5 11	11 3	86	2·0	4·0	N.	1·0	1·0	5·0	0·5	1·5	Tr.
		12.1.12				86				1·0	1·0	4·5	0·5	1·0	Tr.
		19.1.12				82				1·0	1·0	4·5	0·5	1·5	Tr.
30	E. W. G.	14.12.11	21	5 11	10 10	66	2·0	3·75	N.	0·5	0·3	6·0	1·0	1·0	0
31	R. L. H.	14.12.11	22	5 5·5	11 3	75	2·0	3·75	N.	0·5	1·0	6·5	2·5	2·0	Tr.
		17.1.11				65				0·5	1·0	6·5	2·5	2·3	Tr.
32	R. O. E.	12.12.11	19	5 11·2	9 3	70	2·25	3·75	N.	1·0*	0·3	3·5	2·5	2·0	Tr.
33	R. D. K.	12.12.11	20	5 9·5	10 0 (approx.)	69	1·75	3·25	N.	0·5	1·0	10·5	6·0	2·5	Tr.
34	F. J. C.	14.12.11	33	5 8·5	10 0	82	2·12	3·5	N.	0·5	0	4·5	0·5	1·0	Tr.
35	B. N. N.	12.12.11	23	5 10	11 7	60	2·0	3·5	N.	0·3	1·0	8·5	2·0	2·5	Tr.
36	E. R. M.	5.12.11	19	4 8·5	9 12	72	1·75	3·5	Cardio-pulm. murmur	0·7	1·0	8·0	2·5	2·5	?
37	E. M. C.	8.12.11	25	5 7	10 7	62	1·5	4·5	N. 3rd sound	0·5	0·5	6·0	1·5	2·5	Tr.
38	E. A. G.	5.12.11	24	5 7	10 10	86	1·75	4·25	N.	0·5	1·5	7·0	0·7	1·5	Tr.
		8.1.12				102									
		9.1.12				75				0·5	1·5	6·0	0·7	1·0	Tr.
39	M. V.	6.11.11	24	5 5	10 2	82	2·25	4·0	N.	0·7	2·0	12·0	1·0	4·0	Tr.
40	F. B. V.	12.12.11	23	5 3	10 2	54	2·12	3·75	N. 3rd sound	0·7	0·7	12·0	2·5	5·5	0

III—*continued.*

Lead *II.*						*P–R* inter-val.	Lead *III.*						Deflection time.	Remarks.†
P.	*Q.*	*R.*	*S.*	*T.*	*U.*		*P.*	*Q.*	*R.*	*S.*	*T.*	*U.*		
1·0*	1·5	11·5	0	1·0	Tr.	0·13	1·0*	1·0	10·0	0·5	0·5	Tr.	0·023 ap.	α (twice), δ, ε.
1·0*	1·5	13·0	0	3·0	Tr.	0·15	1·0*	1·0	10·0	0	1·5	Tr.	0·016	
1·0*	1·5	13·0	1·0	3·0	Tr.	0·15	1·0*	1·0	10·0	0	1·5	Tr.	0·013	
1·0	1·0	9·0	1·0	2·0	Tr.	0·15	1·0	1·0	7·0	0·5	0·5	0	0·023 ap.	Asthma.
1·0	1·0	9·0	2·0	1·5	Tr.	0·13	1·0	1·0	7·5	1·0	0	?	0·016	
1·5	1·5	10·0	1·0	1·5	Tr.	0·13	1·0	2·0	7·0	Tr.	0·5	?	0·023 ap.	α, γ.
1·3	1·0	13·5	1·0	3·0	Tr.	0·21	1·0	1·0	12·0	1·0	1·3	Tr.	0·013 ap.	α, η, sore throats.
1·5*	Tr.	15·0	2·0	2·0	0·5	0·16	1·0*	0	11·0	2·0	1·0	Tr.	0·023 ap.	α, smallpox, dysentery, relapsing fever, malaria.
1·0*	0·5	13·0	2·0	1·5	0·5	0·15	1·0	1·0	6·0	1·0	Tr.	?	0·016 ap.	
1·5*	0·5	14·0	2·5	2·5	0·5	0·16	1·0*	0·5	11·0	2·0	1·5	Tr.	0·013	
1·5*	0·5	15·5	2·5	2·0	0·5	0·15	1·0*	0	10·0	2·0	1·0	Tr.	0·015	
1·0	2·0	13·0	2·0	+2·0 −0·5	Tr.	0·15	1·0	1·5	8·5	0	1·0	0	0·013 ap.	α, δ, ζ, quinsy, tonsillitis often.
1·0*	1·0	9·5	0	3·5	Tr.	0·13	1·5*	0·5	5·0	0	1·3	Tr.	0·023 ap.	α, malaria, bronchitis.
1·0*	1·0	10·0	0	3·5	Tr.	0·13							0·013 ap.	
1·3*	1·0	11·0	0	5·0	Tr.	0·13	1·0*	0·5	6·5	0	1·7	Tr.	0·015	
1·0*	0·7	8·5	0·5	3·0	Tr.	0·16	0·5*	1·5	4·0	0·5	1·0	0	0·023 ap.	α, δ.
1·0*	0·7	9·5	0·5	3·0	Tr.	0·16	0·5*	1·5	3·5	0	Tr.	?	0·023	
1·0*	1·0	8·5	1·5	2·5	Tr.	0·15	0·5*	1·0	5·0	1·0	0·5	?	0·016	
1·0*	1·0	10·0	0·5	1·0	Tr.	0·13	0·7	0·5	6·5	0·5	0·5	Tr.	0·023 ap.	α, δ, η (twice), sore throats, Vincent's angina eight years ago.
1·0*	Tr.	9·0	1·0	1·5	Tr.*	0·15	0·7	0	5·0*	1·3	0	0	0·025	γ, ε, typhoid.
1·0*	Tr.	9·0	2·0	1·5	Tr.*	0·15	0·5	0	5·0*	2·0	0	0	0·018	
1·0*	Tr.	10·0	2·0	1·5	Tr.*	0·15	0·5	0	5·5*	2·0	0	0	0·011	
1·0	1·0	14·0	1·5	4·5	0	0·13	0·5	0·3	9·0	2·0	3·0	0	0·013 ap.	α.
1·0	1·0	11·0	3·5	3·0	Tr.	0·16	1·0	1·0	7·0	1·0	0·5	?	0·013 ap.	α, β, γ, δ.
1·0	1·0	11·0	3·3	3·5	Tr.	0·16	0·7	0·5	5·0	1·0	0·5	?	0·011	
1·0*	0·5	9·0	3·0	2·7	Tr.	0·16	0·5	1·0	6·0	2·5	0·5	0	0·013 ap.	α.
1·5	1·0	13·0	4·0	2·0	Tr.	0·16	1·5	0	7·0*	0	−2·0	?	0·013 ap.	α, winter colds, appendicitis.
1·7*	Tr.	9·5	4·5	2·3	Tr.	0·16	1·0	Tr.	3·0	4·0	1·5	Tr.	0·013 ap.	α, septic cellulitis of arm.
1·0*	1·0	14·0	3·0	3·0	Tr.	0·16	0·5*	1·0	5·0*	2·0	0·5	Tr.	0·013 ap.	α, β, γ, ε, chronic sore throat.
1·3	2·0	13·5	4·0	1·5	?	0·15	0·7	1·0	6·0*	1·5	−1·0 +0·5	?	0·023 ap.	α, γ, δ.
1·0	1·5	16·5	2·0	4·0	0·5	0·16	+0·3	0·5	5·5	0	+0·5 −0·5	?	0·023 ap.	α, γ, δ.
1·5	1·5	11·0	1·5	2·0	Tr.	0·16	1·5	0·5	2·5	1·0	−0·5 +0·5	?	0·023 ap.	α, γ, ζ.
1·5	1·5	11·0	2·5	Tr.	?	0·16	1·5	0·5	2·5	1·5	−0·5 +0·5	?	0·016 ap.	
1·0	1·0	10·0	2·5	1·0	Tr.	0·18							0·016	
1·5*	1·5	12·0	0	2·5	Tr.	0·13	1·0*		+4·0 −1·0		−1·0	0	0·016	α, δ, η, tonsillitis.
1·0	0	9·5	0·5	3·5	0	0·15	0·3		+6·0 −2·0		−1·5	?	0·013 ap.	α, γ, tonsillitis.

TABLE

No.	Initials.	Date.	Age.	Height.	Weight.	Heart rate.	Heart limits.		Heart sounds.	Lead *I*.					
							Right.	Left.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.
				ft. in.	st. lb.										
41	O. M.	31.10.11	33	5 9	11 5	78	2·0	4·5	N.	0·7	1·5	7·7	1·0	2·5	Tr.
		19.1.11				86				0·7	1·5	7·7	2·0	2·5	Tr.
42	H. D.	5.12.11	23	5 9	13 1	106	2·0	4·25	N.	0·5	1·0	7·0	Tr.	2·0	Tr.
		12.1.12				88				0·5	1·0	6·5	1·0	2·0	Tr.
		12.1.12				95				0·5	1·0	6·5	1·0	2·0	Tr.
43	A. K. C.	12.12.11	28	6 0	11 2	90	2·5	4·0	N.	0·5	1·0	4·0	1·0	1·5	Tr.
44	J. B. V.	5.12.11	23	5 4 approx.	9 0 approx.	78	1·75	4·5	N.	0·5	0·5	8·0	1·5	2·0	0
		21.1.12				82				0·5	0·5	5·0	2·5	1·5	0
45	P. H.	12.12.11	19	5 9	11 0	54	2·0	3·5	N. 3rd sound	0·5	1·0	7·0	3·0	+1·0 −0·5	Tr.
46	M. H. B.	30.10.11	18	5 4	8 0	82	1·25	4·0	N.	0·5	1·0	8·0	1·0	2·5	0
47	L. T.	7.12.11	25	5 8	10 9	69	2·0	4·5	N.	0·7	0·5	6·5	1·5	3·0	Tr.
		19.1.12				76				0·5	0·5	6·5	2·0	2·0	Tr.
48	E. B. J.	7.12.11	25	5 7·5	10 3	53	2·5	4·0	N. 3rd sound	0·5	0·5	7·0	2·0	2·5	0
		9.1.12				69				0·5	0·7	9·5	3·0	3·0	Tr.
		9.1.12				75				0·5	0·7	9·5	3·0	3·0	Tr.
49	W. J. M.	5.11.11	27	5 8	10 10	69	2·0	4·25	N.	0·5	0·5	5·5	0	2·0	0
		15.1.12				95				0·5	0·5	6·0	0	1·5	Tr.
50	G. C. C.	30.10.11	35	5 7	9 7	70	1·5	3·5	2nd reduplic. at apex. and pulm.	0·7	1·0	4·5	1·0	2·5	Tr.
		19.1.12				88				0·7	1·0	4·5	1·0	2·0	Tr.
51	R. H. L.	20.12.11	23	5 7	10 0	66	2·0	3·75	N.	0·7	1·0	5·5	1·0	2·3	Tr.
		17.1.12				60				0·7	1·0	5·0	1·0	2·3	Tr.
		17.1.12				76				0·7	1·0	5·5	1·0	2·7	Tr.
52	W. E. K.	12.12.11	23	5 7	10 12	48	2·25	3·75	1st sound redupl.	0·3	0·5	5·5	2·5	3·5	0

Measurements of the Curves of Fifty-two Normal Subjects.

The Summit P.—*P*, the auricular summit, has been constantly found in all instances, and in each lead. It consists in the main of an upward deviation, the limits of which lie between a trace* and 1 mm. in lead *I*, a trace and 1·7 mm. in lead *II*,† a trace and 1·5 mm. in lead *III*.

P has bifurcated at its summit in a number of instances, and this bifurcation must be regarded as a normal feature of many curves, from whichever lead such curve is

* By a trace we wish to express an observed measurement which is less than 0·3 mm.

† This limit is commonly surpassed in clinical cases of mitral stenosis.

III—*continued.*

Lead *II*.						*P–R* inter-val.	Lead *III*.						Deflection time.	Remarks.†
P.	*Q*.	*R*.	*S*.	*T*.	*U*.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.		
1·5	0·5	7·5	0·5	2·5	Tr.	0·16	1·0		+2·0	−1·5	−0·5 +1·0	?	0·016 ap.	Nil.
1·5	0·5	7·0	0·5	2·5	Tr.	0·16	1·0		+2·0	−1·5	−0·5 +1·0	?	0·011	
1·5	0	8·5	2·0	2·5	Tr.	0·16	1·0		+2·5	−2·0	0·5	?	0·023 ap.	α, η.
1·5	0	8·5	2·0	2·5	Tr.	0·16	1·0		+2·5	−2·0	Tr.	?	0·020	
1·5	0	9·0	2·0	2·5	Tr.	0·16	1·0		+2·5	−2·0	Tr.	?	0·010	
1·7	Tr.	7·5	2·0	1·7	Tr.	0·16	1·5		+2·0	−2·0	1·0	Tr.	0·013 ap.	Smallpox, malaria.
1·0*	0·3	5·5	2·0	1·0	Tr.	0·13	0·5*		−2·0	+0·5	−1·0	0	0·023 ap.	Malaria.
1·0*	0·3	4·0	2·0	1·0	Tr.	0·13	0·5*		+2·0	−3·0	Tr.	0	0·014 ap.	
0·7	Tr.	8·0	1·0*	+1·0 −0·5	0	0·15	Tr.		+3·0	−2·0	Tr.	?	0·013 ap.	α, ε, typhoid, jaundice.
1·5	Tr.	8·2*	2·0*	1·5	Tr.	0·17	1·0		+2·0	−2·0	−0·7	0	0·016	Furunculosis (recently).
1·5*	0	10·5	2·0	+4·0 −0·5	Tr.	0·15	0·5		+2·0	−1·0	1·0	0	0·023 ap.	α, β, ζ.
1·0*	0	8·0	2·0	+3·0 −0·5	Tr.	0·15	Tr.		+1·0	−2·0	Tr.	0	0·011	
Tr.	1·0	10·0	1·0	2·5	0	0·2	Tr.		+2·5	−1·5	−1·0	?	0·023 ap.	α, β, ε.
1·0	1·0	9·0	1·5	2·0	Tr.	0·2	Tr.		+3·0	−3·5	−1·5	?	0·021	
0·7	0·5	8·5	2·0	2·0	Tr.	0·2	Tr.		+2·0	−2·5	−1·5	?	0·013	
0·7	0	5·0	2·5	2·0	0·7	0·15	0·7		+2·0	−3·0	Tr.	0	0·023 ap.	α, ζ, bronchopneumonia.
0·7	0	5·0	2·5	2·0	0·5	0·15	0·5		+2·0	−4·5	Tr.	0	0·013	
1·5	0·5	6·7	2·0	4·0	Tr.	0·16	1·3		+4·0	−1·0	2·5	0	0·016 ap.	δ.
1·5	0·5	7·0	2·0	3·0	Tr.	0·16	1·3		+4·0	−1·0	2·0	0	0·013	
1·3	0	7·0	4·0	2·5	Tr.	0·13	1·0	0	2·0*	3·5	Tr.	0	0·020	α, η, sore throats often.
1·0	0	7·0	3·5	2·0	Tr.	0·13	1·0	0	2·0*	3·0	−1·0	0	0·020	
1·3	0	7·0	4·0	2·5	Tr.	0·13	1·0	0	2·0*	4·0	−1·0	0	0·016	
1·0	0	7·0	3·5	4·0	0	0·16	0·3	1·0	2·0	3·5	0·5	0	0·013 ap.	α (twice), γ, tonsillitis.

taken.* It has been found twice in lead *I*, 17 times in lead *II* (figs. 2, 8, and 16 *III*), and 10 times in lead *III*.

Splitting in lead *I* or in lead *II* has never been observed except in conjunction with splitting in lead *II*.

The Depression Q.—Q, the first ventricular variation, was found in 37 instances in lead *I*, in 45 instances in lead *II*, and in 36 instances in lead *III* (the 12 instances in which Q, R, and S are bracketed are excluded; Q^3 was present, therefore, in 36 out of 40 instances). The limits of measurement in lead *I* varied from 0 mm. to

* Bifurcation of *P* has been commonly regarded as a sign associated with hypertrophy of the auricular portion of the heart. This footnote and those which succeed it, and refer to clinical findings, are given as explanatory of the general purpose of our observations rather than as statements of fact.

2·0 mm., in lead *II* from 0 mm. to 2·5 mm., in lead *III* from 0 mm. to 2·5 mm. (the last limit is 4·5 if the downward deflections of the bracketed curves are included).

The Summit R.—*R* has been present in all instances and in all leads. The limits of its variation have been from 1·5 mm.* to 12 mm.† in lead *I*, from 4 mm. to 16·5 mm. in lead *II*, and from 2 mm.‡ to 14 mm.§ in lead *III*.

Splitting of *R* is comparatively rare; it has been seen in lead *I* in three instances; in lead *II* in one instance; in lead *III* it has been present in six instances (fig. 4), in which the question of its identification was not complicated.|| In 11 other instances, of which we shall speak more fully, *R* might also be considered split; these are the cases in which, in lead *III*, a number of small upward and downward variations open the ventricular systole (so-called splintering; see fig. 3). Such curves are bracketed in Table III and are found together, namely, Nos. 39–50.

The Depression S.—*S* has been found in 50 instances in lead *I*, in 49 instances in lead *II*, and in 31 instances in lead *III* (the 12 instances in which *Q*, *R*, *S* are bracketed are excluded; S^3 was present, therefore, in 31 out of 40 instances). The limits of *S* in lead *I* have been 0–6 mm.,¶ in lead *II* 0–4·5 mm., in lead *III* 0–4 mm.** (the last limit becomes 4·5 if the downward deflections of the bracketed curves are included). Splitting of *S* has never occurred in lead *I*; it has been present in two instances in lead *II*. Apart from the 11 cases of splintering in the opening events of ventricular systole, a division of *S* has not been seen in lead *III*.

The Summit T.—Some trace of *T* has been present in all subjects and in all leads. As a rule, it takes the form of the generally recognised variation, a gradual rise and a steeper fall. Its limits in lead *I* have varied from 0·5 to 5·5 mm. Lead *I* has never shown complete inversion, that, is to say, *T* has never been a purely downward deflection in this lead. But it has shown partial inversion in one instance, a small downward deflection being succeeded by a small upward one. In lead *II* the maximal upward deflection of *T* has reached 5 mm., the minimal being no more than a trace. Complete†† or partial inversion in lead *II* has not been seen. In lead *III* the maximal deflection has been 3 mm. Complete inversion (figs. 4, 5, 7, and 15, *III*)

* This limit is commonly passed and R^1 is uniformly small in clinical cases in which, as in mitral stenosis, there is reason to believe right-sided hypertrophy of the heart is present.

† R^1 appears to be uniformly tall when there is clinical evidence of left-sided hypertrophy.

‡ This limit becomes 0·5 if the bracketed curves are included. R^3 is generally of small amplitude when there is evidence of left-sided hypertrophy.

§ R^3 is generally tall when there is evidence of right-sided hypertrophy.

|| Splitting of *R* is not at all uncommon in pathological cases, though its significance is at present unknown.

¶ The last limit is commonly surpassed in clinical cases in which there is evidence of right-sided hypertrophy.

** This limit is commonly surpassed, and *S* appears to be uniformly deep in clinical cases where there is considerable hypertrophy of the left ventricle.

†† Complete inversion of T^2 is commonly manifested by pathological hearts, and such inversion is regarded as a sign of value in prognosis.

has been seen in eight instances, the greatest extent of the downward deflection being 2 mm. Partial inversion occurred in six additional instances. Complete inversion of *T* must consequently be considered a rare or abnormal event in all leads except *III*, and in this it is usually associated with splintering of the curve in its opening ventricular events (Nos. 39–50).

The Summit U.—The summit *U*, for which we have arranged a column in Table III, was first described by EINTHOVEN in 1906,* and an illustration of it was given in fig. 23 of his paper. In the particular instance referred to, the amplitude of *U* was well-nigh 1 mm., the largest excursion so far recorded.

U has been seen in a large percentage of the 52 normal electrocardiograms examined. It has been definitely present, in one form or another, in 32 cases (out of 49) in lead *I*, in 44 cases (out of 49) in lead *II*, and in 14 (out of 30) cases in lead *III*. The summit varies very much, both in size and form, from subject to subject. It is seen most prominently in lead *II*, and here its maximal limit has reached 0·8 mm. in our series. If fig. 8 be examined, the wave in question will be seen following directly upon *T*; its approximate duration is 0·16 sec., and it is followed by a long horizontal line, which occupies diastole.

In such a curve as that shown, the variation is upwards; here, as in EINTHOVEN'S original curve, *T* fails to reach the base line, running as it does into *U*. Thus the down stroke of *U* is of greater amplitude than the up stroke. Such prominent *U* variations are found as accompaniments of slow heart rates, and are especially prominent where *T* is of considerable amplitude. *U* variations of this magnitude are comparatively rare, but waves of smaller amplitude are extremely common. A slight bowing of the whole line which joins the end of *T* and the beginning of the succeeding *P* is seen in figs. 9, 15, *II*, and 16, *II*. A similar bowing, though less sustained, is seen in fig. 14, *II*. But the curves, in which this bowing occurs, show all the transitions to another type of deflection, which is seen in fig. 12, *II*, and this transition occurs not only from subject to subject, but in the same subject from time to time (figs. 12 and 14). The type of curve to which we refer, and which stands at the one end of the transition, is illustrated by fig. 12, *II*; it may be read as a small, downwardly directed deflection, following directly upon the *T* summit. It is seen even more prominently in lead *I* of the same figure.

KRAUS and NICOLAI, in their recent publication,† have referred to a depression in this situation and, according to their nomenclature, it is termed *Fp*. Especial reference is made to the downwardly directed form, and the transitions between it and the upwardly directed *U*, because, when there is slight shifting of the electrocardiogram as a whole, so that the horizontal line of the pause does not run quite parallel to the millimetre abscissæ, it is often difficult to give accurate numerical expression to this portion of the curve in such a table as we now publish. Where

* "Le Télécardiogramme," 'Archives Internationales de Physiologie,' 1906, vol. 4, p. 149.

† 'Das Electrokardiogramme,' Leipzig, 1910.

the depression is definite, we have included it in the column for the T variation as a minus quantity. It must be clearly distinguished in such a table from partial inversion of T, such as is seen in fig. 3, and such as is expressed in our table by a minus quantity followed by a plus quantity.

So far as we are aware, no attempt has been made to settle the relation of the U variation to the end of ventricular systole. Where it consists of a slight bending of the whole line joining the termination of T and commencement of the succeeding P (figs. 9, 15, *II* and 16, *II*), the estimate is unnecessary. But it becomes essential* where U is a prominent variation limited to late systole or early diastole, as in fig. 8; and this is especially the case since EINTHOVEN, in his original description of it, concluded that it belongs to systole.

We have consequently used the instances in which it was most prominent in our series for this purpose, taking simultaneous electrocardiographic and carotid curves. The U variation in fig. 17 has an approximate duration of 0·16 sec. The bottom of the dicrotic notch d is marked upon the carotid curve, and an interval of 0·03 sec. is allowed for transmission delay in the recording instrument (see fig. 18), a further interval of 0·03 sec. is allowed for transmission delay from aorta to carotid,† and the corresponding point is fixed in the electrocardiogram. The curve shows that the variation U lies almost entirely subsequent to semilunar closure. The semilunar closure is estimated as falling a fraction of a second after the downstroke of T. The second sound has been estimated by KAHN‡ as occurring 0·03 sec. after the downstroke of T. In our own curves the interval is somewhat smaller, but the difference is unessential. U, as a prominent variation, must be regarded, therefore, as almost, if not entirely, a diastolic event.

The Average Amplitudes of the Summits and Depressions.

In estimating the average amplitude of the summits and depressions in the table, we have used those curves which correspond to the smallest deflection time, and have omitted all the tabulated measurements where the deflection time has exceeded 0·018 sec. In all but one instance the deflection times have been as low as 0·016 sec. The calculated values are consequently based upon the curves of 44 subjects. Where a "trace" is tabulated as the value of a summit, we have taken the value at 0·15 mm. In the instance of splintering we have allowed the

* The variation U occurs in the electrocardiograms of pathological subjects, and a thorough knowledge of its relation to other events of the cycle is desirable, for it may be confounded with additional P summits, a matter of much importance when the presence or absence of heart-block has to be determined.

† The allowance of 0·03 second for the transmission time from heart to carotid is taken from our general knowledge of it in other cases. The possible error is probably not greater than 0·01 second. The full delay from apex to carotid in this instance was measured at 0·08 second, and 0·05 second is the customary allowance for the presphygmic interval.

‡ 'Archiv f. d. ges. Physiol.,' 1910, vol. 133, p. 597.

plus quantity as R and the minus quantity as S. Estimated in this fashion the value in millimetres, or ten thousandths of a volt, for the summits and depressions of the three leads, are as follows :—

Lead *I*.						Lead *II*.						Lead *III*.					
P.	*Q*.	*R*.	*S*.	*T*.	*U*.	*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.	*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.
0·52	0·51	5·16	2·06	1·93	0·10	1·16	0·73	10·32	2·23	2·46	0·16	0·81	0·86	6·61	1·73	0·61	0·06

The estimate shows that the average values of the summits and depressions have the following relation to each other in the separate leads :—

$$P^2 > P^3 > P^1 \qquad S^2 > S^1 > S^3$$
$$Q^3 > Q^2 > Q^1 \qquad T^2 > T^1 > T^3$$
$$R^2 > R^3 > R^1 \qquad U^2 > U^1 > U^3$$

With the exception of Q, which has its greatest average value in lead *III*, the remaining summits and depressions have their greatest values in lead *II*; this fact is an argument in favour of the adoption of lead *II*, when a single lead is alone employed. Three of the deflections, P, Q, and R, have their smallest average values in lead *I*, and three, S, T, and U, in lead *III*.

*The P–R Interval.**—The measurement of P–R intervals has been taken in lead *II* only, because P is usually most prominent in this lead. The measurements in lead *I* and lead *III* are generally within a hundredth of a second of this measurement, but there may be slight differences from lead to lead. The limits of duration of the P–R interval are 0·13 to 0·21 sec.; and these measurements apply to heart rates varying from 48 to 109 per minute. The most frequent measurements are from 0·13 sec. to 0·16 sec. The maximum value, 0·21, occurred on a solitary occasion, and 0·18 and 0·19 are infrequent in incidence. There is little relation between the length of the P–R interval and the heart rate in our series; the only noteworthy relations being that measurements exceeding 0·16 sec. do not occur with heart rates exceeding 90, and that when the heart rate exceeds 100, the measurement 0·13 sec. becomes, relatively, much more frequent. A P–R interval exceeding 0·16 sec., and accompanying a heart rate of 90 or over, should be considered pathological, and a P–R interval exceeding 0·20 sec. should be considered pathological in all but exceptional instances, whatever the heart rate may be.†

* We have preferred the P–R interval to the P–Q interval, a measurement sometimes adopted, because, although the latter gives perhaps a more accurate reading of any given conduction time, it is not always obtainable. By adopting the P–R interval, a uniform standard is obtained. The P–R interval is of considerable pathological and clinical importance.

† The final conclusions are based, not only upon the 52 normal subjects, but upon measurements in several hundred additional subjects, normal and abnormal.

Grouping of Electrocardiographic Curves.

In arranging the table of observations, we have attempted to group the electrocardiograms so that curves which are similar lie adjacent to each other in the horizontal columns. The arrangement of the curves in this manner has shown that electrocardiograms from normal subjects may be massed into three chief groups, not sharply defined at their borders, but showing a gradual passage of form from one group to the other. The first group consists of electrocardiograms in which *R* is small in lead *I* and is larger in lead *III* (Nos. 1–25, fig. 15); the third group (Nos. 38–52) is characterised by a relatively conspicuous *R* in lead *I* and a small or splintered *R* in lead *III* (fig. 16).

The arrangement is of more interest because an increase of *R* in lead *III*, with a diminution of *R* in lead *I*, is considered evidence of hypertrophy of the right ventricular muscle as opposed to the left; and because an increase in the amplitude of *R* in lead *I*, and a diminution of it in lead *III*, is considered evidence of hypertrophy of the left ventricle as opposed to the right (EINTHOVEN*).

As an extreme example of curves from a normal subject, which approach very closely to those which may be considered as characterising right-sided hypertrophy,† we publish fig. 15. The divergence from the mean which is shown by this particular set of curves is so great that we were for some while undecided whether it should be included in the series or not, and this the more, while a history of bronchitic troubles was obtained. But, eventually, when we could find no other physical sign to arouse suspicion of cardiac abnormality, we determined upon its inclusion. As an instance of what might be regarded as a full expression of right-sided hypertrophy, we may cite No. 59, Table IV, one of our rejected cases; in these curves, *S* reaches 7 mm. in lead *I*, and *R* measures 17 mm. in lead *III*, while *R* sinks to 5 mm. in lead *I*.

At the other end of the series is such a curve as fig. 16, where *R* is tallest in lead *I* and short in lead *III*, while *S* is deepest in lead *III*. As an instance of what might be regarded as a fairly full expression of left-sided hypertrophy we may cite No. 58, Table IV, again a rejected subject; in this instance *R* reaches 15 mm. in lead *I*, *S* reaches 9 mm. in lead *III*, while *R* in lead *III* is but 3·5 mm.

Emphasis is laid upon these types of curves, and more especially upon the extreme instances, which we have quoted and figured, because they will be of importance in the ultimate solution of the enquiry as to what extent right- or left-sided cardiac hypertrophy can be identified in electrocardiographic curves.

At an earlier stage a type of electrocardiogram was mentioned, which is seen in lead *III*, and in which the identification of the electric variations at the opening of

* EINTHOVEN, 'Archiv f. d. ges. Physiol.,' 1908, vol. 122, p. 517; and previous citation.

† It not only resembles them in respect of the small *R* in lead *I* and the highest *R* in lead *III*, but also in respect of the deep *S* in lead *I*.

the ventricular systole is difficult or impossible. The subjects from whom the curves were obtained are tabulated as Nos. 39–50, and examples of the curves are shown in figs. 3, 5, 6, and 7. The detailed form is very varied from subject to subject, though remarkably constant in a given subject from time to time. We have specially considered the type because it must be regarded as a normal form of electrocardiogram, because it is commonly associated with partial or complete inversion of T, and, finally, because reference to it is necessary in order that our method of tabulating it should be clear.

In figs. 3, 5, 6, and 7, curves taken from four subjects are shown. In the first of the series, fig. 3, there is splintering, the opening events consisting of two summits and a depression. Fig. 5 shows minute downward, upward and downward deflections. Fig. 6 presents a small upward deflection and a deep depression, which is split. Finally, in fig. 7, the opening events consist of a deep downward deflection followed by an upward deflection of almost similar extent; it is a curious curve, but has been met with on other occasions, though, in the present series, the type has not been repeated. In none of these four curves (figs. 3, 5, 6, and 7) is it possible to apply the usual lettering to the opening phases of ventricular systole. A curve (fig. 4), approaching very closely to the same types, may be said to consist of a split summit R, followed by a depression S.

The Seven Rejected Subjects.

We have stated that, of 59 students investigated, seven have been rejected; the rejections were made either because of abnormal signs obtained in the ordinary physical examination or, as in one instance, upon the appearance of the electrocardiograms themselves.

It may appear that the number of rejections, which is approximately 12 per cent. of the total number of hearts examined, is excessive; but we think it desirable that the tests should be stringent. When the left heart limit has exceeded 4·5 inches, when there have been occasional premature contractions, when there have been cardiac murmurs, whether mitral systolic or tricuspid systolic, the subjects have not been included in the series; six cases fall into this category. One additional case has been rejected on the appearance of the electrocardiograms alone.

The rejections are tabulated in Table IV. The first two subjects of this table showed electrocardiograms which fall within the limits defined by the 52 subjects of Table III in every respect. One was rejected on account of a systolic tricuspid murmur (No. 53), the other on account of the extension of the left heart limit to 5 inches (No. 54).

Four of the remaining subjects (Nos. 55–58) were primarily rejected on the ordinary physical signs, thus, No. 55 presented an apical systolic murmur. In No. 56 the left heart limit extended to 5·5 inches, and occasional premature beats

TABLE

No.	Initials.	Date.	Age.	Height.	Weight.	Heart rate.	Heart limits.		Heart sounds.	Lead *I*.					
							Right.	Left.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.
				ft. in.	st. lb.										
53	J. H. L.	11.12.11	29	5 9·5	11 0	100	2·5	3·75	Systolic tricuspid	1·0	1·5	7·0	3·0	1·5	Tr.
54	G. B. K.	8.12.11	24	5 10	14 0	52	2·0	5·0	N.	1·0	0·5	11·0	0	3·0	0
55	W. B. S.	14.12.11	24	5 10	10 0	78	1·5	3·75	Apical systolic murmur	0·7*	0	5·0	3·5	2·0	Tr.
56	L. A. D.	8.12.11	23	5 9	11 0	68	1·75	5·5	Occasional premature beats	0·3	0	5·0	8·0	3·0	0·5
57	D. P.	5.12.11	23	5 1·5	9 0	76	2·5	5·5	N.	0·5	1·0	9·5	2·0	2·5	0
58	J. B. D.	11.12.11	26	5 5·5	9 4	86	2·0	5·0	Apical systolic murmur	0·5	0·5	15·0	0	1·0	0
59	P. V. E.	8.12.11	25	5 11	11 0	60	2·25	4·25	N.	1·0	0	5·0	6·0	+3·0 −0·5	0
		15.1.12				78				1·0	0	6·0	7·0	+3·0 −0·5	0
		15.1.12				78				1·0	0	5·0	7·0	+3·0 −0·5	0

† α = measles; β = mumps; γ = chicken-pox; δ = whooping cough;

were present. In No. 57 and No. 58 the left limit was excessive, 5·5 and 5 inches respectively, and in the last instance a systolic apical murmur was also present.

It seems to us especially noteworthy that of the six rejected subjects to which we have so far referred four presented electrocardiograms of distinctly divergent types. The features which appear to us unusual in the electrocardiograms are given in the ensuing paragraphs.

No. 55.—While the height of *R* in lead *II* reaches 16·5 mm., that is to say, while it attains the maximal limit reached in the remainder of the series, in lead *III*, *R* slightly exceeds the maximum, being 14·5 mm. In this case we lay stress, not so much upon the attaining of the maximal limit, but upon its attainment in *two distinct leads.*

No. 56.—These curves are exceptional, because the maximal limit is exceeded in four separate respects. In lead *I*, *S* measures 8 mm.; in lead *II*, *P* measures 2 mm. and *S* measures 8 mm.; in lead *III*, *P* measures 2 mm.

No. 57.—The exceptional feature of the curves is the excess of *R* in lead *II*, where it amounts to 20 mm.

No. 58.—The exceptional features consist of an increase of *R* to 15 mm. in lead *I*, and an increase of *S* in lead *III* to 9 mm.

We are left with a single subject (No. 59). In this instance no abnormality could be found from the ordinary physical examination of the heart. But the shape of the electrocardiograms is such that we are disinclined to include them in our series

IV.

Lead *II*.						*P–R* interval.	Lead III.						Deflection time.	Remarks.†
P.	*Q*.	*R*.	*S*.	*T*.	*U*.		*P*.	*Q*.	*R*.	*S*.	*T*.	*U*.		
1·5	0·5	16·0	2·0	1·5	?	0·13	0·3		+5·0 −2·0		−1·0	?	0·013 ap.	Sore throats often, till tonsils removed two years ago; influenza.
1·0	0	10·0	1·0	3·0	0	0·16	Tr.	0	2·0*	2·0	−1·0	0	0·023 ap.	Nil.
1·3*	2·0	16·5	2·5	3·0	0·5	0·16	0·7	2·0	14·5	2·0	2·0	Tr.	0·023 ap.	α, β, ζ, appendicitis in September, 1911.
2·0	1·0	11·0	8·0	3·5	Tr.	0·18	2·0	2·0	6·0	3·0	Tr.	?	0·023 ap.	α, γ, muscular rheumatism.
1·0	0	20·0	1·0	2·0	Tr.	0·13	1·0	0	11·0*	0	0·5	?	0·023 ap.	α.
1·0	0	13·0	3·0	1·7	0	0·13	0·5	0	3·5*	9·0	Tr.	0	0·013	α.
1·0	1·0	12·5	1·5	3·5*	Tr.	0·15							0·023 ap.	α, δ, ε, η.
1·0	1·0	15·0	1·5	3·0	Tr.	0·15	0·5	3·5	17·0	Tr.	0·5		0·023	
1·0	1·0	15·0	2·0	3·5	Tr.	0·15	0·5	3·5	17·0	Tr.	0·5		0·013	

ε = influenza; ζ = scarlet fever; η = diphtheria; * split.

of normal curves. The exceptional feature in this case is the tall *R* in lead *III*, where it amounts to 17 mm. The limits are also reached or passed by *S* in lead *I*, the measurement being 6 mm. and 7 mm., and in lead *III* by *Q*, which reaches 3·5 mm.

The Constancy of Electrocardiograms in a Given Individual from Time to Time.

We have repeated the electrocardiographic examination in 26 subjects, sometimes after a few days' interval, sometimes after an interval of a month or more. The comparison of such curves is expressed numerically in Table III (Nos. 1, 3, 7, 9, 11, 12, 14, 15, 16, 20, 21, 24, 26, 27, 29, 31, 38, 41, 42, 44, 47, 48, 49, 50, 51, 59). In 24 subjects we have found quite minor variations in the heights or depths of the several summits or depressions from time to time. A change of more than 1 or 2 mm. in the height of *R*, even when it is of considerable amplitude, is exceptional. The summits and depressions of smaller amplitude vary to little more than a proportional extent, with the exception of *T*, which has shown a greater change in two instances (Nos. 14 and 20). The actual resemblance between such curves is, in reality, but poorly expressed by these measurements. The curves resemble each other most closely in their general outlines, and we offer as an example of such resemblance the accompanying figures (figs. 12 and 13), taken from a single subject, with an interval of 31 days between the sittings.

The longest interval which has elapsed in comparisons of this kind occurred in

No. 16, but applies to lead *I* only. More than two years separate the observations, the first of which was made by Prof. EINTHOVEN with his instrument at Leyden. The comparison of these two curves (figs. 10 and 11) is the more valuable because they form a connecting bridge between series of observations taken with two distinct instruments. The comparison emphasises the accuracy of readings when standardised curves are employed.

Only two of the 26 subjects have shown conspicuous alterations, these are Nos. 24 and 44. In one there was a change in the height of *R* from 11 mm. to 6 mm. and back to 11 mm. in lead *III*. In the other (No. 44) there was a change of *R* in lead *I* from 8 mm. to 5 mm. and further changes in the deflection amplitudes of the bracketed *Q*, *R*, *S* in lead *III*. Considering that the curves as a whole have been taken at different times of the day, with different relations to preceding meals and employment, their relative constancy emphasises the uniformity of the electric discharges of the heart muscle from time to time in a given subject; a conclusion which implies that in any given heart the contraction wave, travelling from sinus to ventricle, follows a beaten track. It also demonstrates the accuracy of the method employed. These findings are in entire agreement with our past experience of pathological cases. Where we deal with patients who are the subjects of chronic heart maladies, the constancy in outline and amplitude of the electrocardiograms, from month to month and year to year, is so striking that no one who has collected a large series of such electrocardiograms can have failed to notice it.

The similarity between the electrocardiograms taken from the same subject on different days is so close, and the variations from subject to subject are so numerous (for it may be said that no two series of curves are ever identical), that a series of three leads from any subject would be sufficient to identify the subject in question amongst a considerable number of his fellows.

Summary and Conclusions.

Our observations appear to us to warrant the following summary and conclusions; the latter are intended to apply to young male adults, and it is hoped they may be of service in identifying curves of a distinctly pathological type:

(1) Distortion of the human electrocardiogram, as a result of slackness of the recording fibre, usually commences to show itself when the calculated deflection time of the string lies between 0·020 and 0·030 sec. Such distortion is but slight quantitatively, but it seems desirable that the smaller value should be recognised as a limit, beyond which it is unwise to proceed.

(2) Bifurcation of the summit *P* is a common event in normal human electrocardiograms and is most frequent in lead *II*.

(3) The depression *Q* is found in the majority of electrocardiograms. It is almost always present in lead *III*.

(4) *R* is always present whatever the lead. Splitting of *R* is occasionally found in

normal curves in lead *I* and in lead *III*. Splintering of the curve during the opening phases of ventricular systole is exceedingly common, though it only occurs in lead *III*.

(5) *S* is almost always present in leads *I* and *II* and usually present in lead *III*; it is generally the first variation to show alteration when the string recording it is too slack. The absence of *S* in a large proportion of a series of curves taken from leads *I* and *II* is an indication that deflection times of too high value have been employed.

(6) *T* is always an upward variation in lead *II*. It may show partial inversion in lead *I* on rare occasions. Partial or complete inversion in lead *III* is relatively common and occurs especially in association with the splintering of curves during the opening phases of ventricular systole.

(7) A variation *U*, which has been described by EINTHOVEN, is present in a large percentage of normal electrocardiograms. It follows the closure of the semilunar valves and stretches into diastole for a variable distance. The whole of the diastolic portion of the curve may be slightly bowed or, on the other hand, a prominent summit may be found in the early part of diastole. It is most prominent and is of most frequent occurrence in lead *II*.

(8) The duration of the normal *P–R* interval, as measured in lead *II*, may vary from 0·13 to 0·21 sec. It usually lies between 0·13 and 0·16 sec. A *P–R* interval which exceeds 0·16 sec. and accompanies heart rates of 90 and over is probably of pathological duration. A *P–R* interval of 0·20 sec. and over is probably of pathological duration in all but exceptional instances, whatever the heart rate may be which it accompanies.

(9) The limits of amplitude for the various peaks and depressions approach the values given in the accompanying table, constructed from our 52 subjects. The values are expressed in tenths of millivolts.

	Lead I.						*Lead II.*						*Lead III.*					
	P.	*Q.*	*R.*	*S.*	*T.*	*U.*	*P.*	*Q.*	*R.*	*S.*	*T.*	*U.*	*P.*	*Q.*	*R.*	*S.*	*T.*	*U.*
Min.	Tr.	0	1·5	0	−0·5	0	Tr.	0	4·0	0	Tr.	0	Tr.	0	2·0	0	−2·0	0
Max.	1	2·0	12·0	6·0	5·5	Tr.	1·7	2·5	16·5	4·5	5·0	0·8	1·5	2·5	14·0	4·0	3·0	0·3

(10) The average values of the summits and depressions in 44 subjects, using deflection times of 0·018 sec. or less, are calculated as follows:—

Lead I.						*Lead II.*						*Lead III.*					
P.	*Q.*	*R.*	*S.*	*T.*	*U.*	*P.*	*Q.*	*R.*	*S.*	*T.*	*U.*	*P.*	*Q.*	*R.*	*S.*	*T.*	*U.*
0·52	0·51	5·16	2·06	1·93	0·10	1·16	0·73	10·32	2·23	2·46	0·16	0·81	0·86	6·61	1·73	0·61	0·06

With the exception of Q, which has its greatest average value in lead *III*, the remaining summits and depressions have their greatest average value in lead *II*; it seems, therefore, that when a single lead is adopted for routine observation, lead *II* should be employed. Three deflections, P, Q, R, have their smallest average values in lead *I*, and three, S, T, U, in lead *III*.

(11) Electrocardiographic curves can be arbitrarily divided into three main groups: the first group, in which R^1 is short and R^3 is high; the second group, in which R^1 and R^3 have fair amplitudes; and a third group, in which R^1 is high, while R^3 is short. These groups are not sharply defined.

(12) In examining a series of 59 subjects, seven were rejected from the normal series for various reasons. Six of these manifested abnormal signs upon the ordinary physical examination, and, of these six, four gave electrocardiographic curves which showed considerable divergence from those of the normal series. We are led from these results to the conclusion that the outline of the electrocardiogram given by individual heart cycles forms a valuable test of the heart's condition, and we consider it probable that when two or more peaks or depressions reach or surpass the limits ascertained in a series of 50 normal subjects, the heart is abnormal.

(13) In normal subjects, standardised curves from the same subject show little or no variation in respect of the amplitude of the summits and depressions, from day to day, from month to month, and from year to year. Yet each subject gives electrocardiograms of distinct forms, and so great is the detailed variation from subject to subject that the recognition of any individual amongst a large number is a matter of no great difficulty from the curves he yields.

DESCRIPTION OF PLATES.

Plate 19.

Fig. 1, *A–F*. (No. 9.)—A series of six electrocardiograms from lead *I*, taken from one subject at one sitting. Each strip of curve consists of two heart beats, and the curve yielded by the string, when a resistance equivalent to that of the patient and the leading-off electrodes replaces the patient, and 1 millivolt is thrown into the galvanometric circuit. Each curve consequently has attached to it a record of the string sensitivity, including a record of its deflection time in its excursion of 1 cm. The deflection times are calculated by subtracting the distance *a–b* from the distance *c–e*. The resultant distance *c–d* is the time occupied by the two movements of the string. The actual deflection time is one-half of this value. The alterations which occur in the measurements and outline of the cardiogram, when the string has varying tensions, are seen. The time-marker is in 1/30 sec. throughout this and all the remaining curves, with the exception of fig. 10.

Fig. 2. (No. 34.)—An electrocardiogram from lead *II*, showing an auricular summit which has a value of 1·7 mm., and which is split at its summit.

Fig. 3. (No. 41.)—An electrocardiogram from lead *III*, showing splintering at the opening events of ventricular systole and partial inversion of *T*.

Fig. 4. (No. 51.)—An electrocardiogram from lead *III*, showing splitting of *R* and complete inversion of *T*.

Figs. 5 and 6. (Nos. 44 and 49.)—Electrocardiograms from lead *III*, showing splintering at the opening events of ventricular systole.

Fig. 7. (No. 48.)—An electrocardiogram from lead *III*, showing a curious arrangement of the deflections which open ventricular systole, and complete inversion of *T*.

Fig. 8. (No. 3.)—An electrocardiogram from lead *II*, showing splitting of *P* and a prominent *U* variation. The latter summit has an approximate duration of 0·16 sec.

Fig. 9. (No. 24.)—An electrocardiogram from lead *II*, showing a *U* variation which consists of a slight bowing of the line which joins the termination of *T* to the commencement of the succeeding *P* summit.

Figs. 10 and 11. (No. 16.)—Two electrocardiograms from lead *I*, taken with an interval of more than two years between them. Each has been standardised in the same manner. The first was taken by Prof. EINTHOVEN in his laboratory at Leyden; the time-marker in this curve is constituted by the vertical lines, which are separated by time intervals of 0·04 sec.

The two curves resemble each other very closely. The chief difference between them is that, in fig. 10, *T* is of somewhat greater amplitude. So far as the remaining summits and depressions are concerned, little difference can be found between them; perhaps *R* is somewhat larger in fig. 10. Both curves show the same exceptional features, namely, a considerable variation in the heights of *R* and *S* from beat to beat. The variation is of similar degree in both curves.

PLATE 20.

Figs. 12, 13, and 14. (No. 14.)—Three photographs, each including electrocardiograms from leads *I*, *II*, and *III*, from the same subject. Figs. 12 and 14 were taken on the same day in quick succession. The deflection time for fig. 12 is 0·012 sec., and for fig. 14 it is 0·022 sec. The two series of curves are almost identical; the actual differences between them are mentioned in the text. The chief difference consists in the presence of a small depression *S* in lead *II* in fig. 12. Fig. 13 was taken from the same subject 31 days earlier; it shows, when compared with fig. 12, that the outline and measurements of electrocardiograms are maintained in

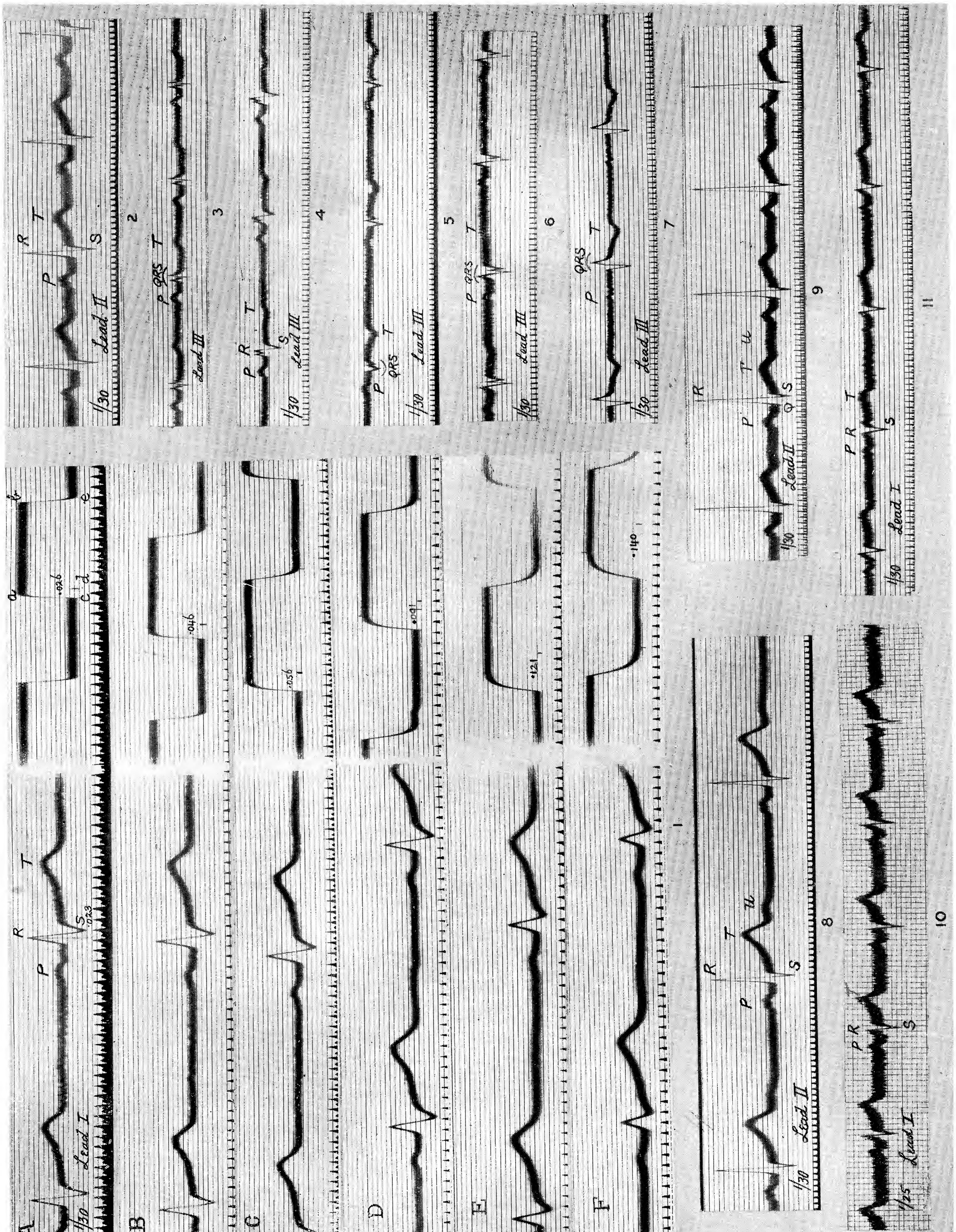
a healthy subject from time to time. Figs. 12, 13, and 14 are also published to show variations in the arrangement of the summit *U*.

Fig. 15. (No. 10.)—Electrocardiograms from the three leads of a normal subject, showing a diminution of *R* in lead *I*, a deep *S* in lead *I*, *R* at its tallest in lead *III*, inversion of *T* in lead *III*, and bowing of the diastolic portion of the curve to form a summit *U*.

Fig. 16. (No. 49.)—Electrocardiograms from the three leads of a normal subject, showing a diminution of the upwardly directed summit at the opening of ventricular systole in lead *III*, *R* at its tallest in lead *I*, a split summit *P* in lead *II*, and bowing of the diastolic portion of the curve to form a summit *U*.

Fig. 17. (No. 3.)—From the same subject as fig. 8; showing the relation of the summit *U* to the carotid curve. The bottom of the dicrotic notch is marked at *d*. An interval of 0·03 sec. is allowed for transmission of the carotid curve through the recording instrument; a further interval of 0·03 sec. is allowed for the transmission of the arterial wave from aorta to carotid. A vertical line is drawn to the electrocardiogram at the point at which the closure of the semilunar valves is estimated to occur. The summit *U* falls subsequent to this point.

Fig. 18 is a curve taken to show the delay in transmission in the recording instrument used for the carotid curve of fig. 17. The delay in transmission amounts to 0·03 sec.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B
C
D
E
F
Lead I
Lead II
Lead III
1/30
1/25
P
R
S
T
QRS
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8
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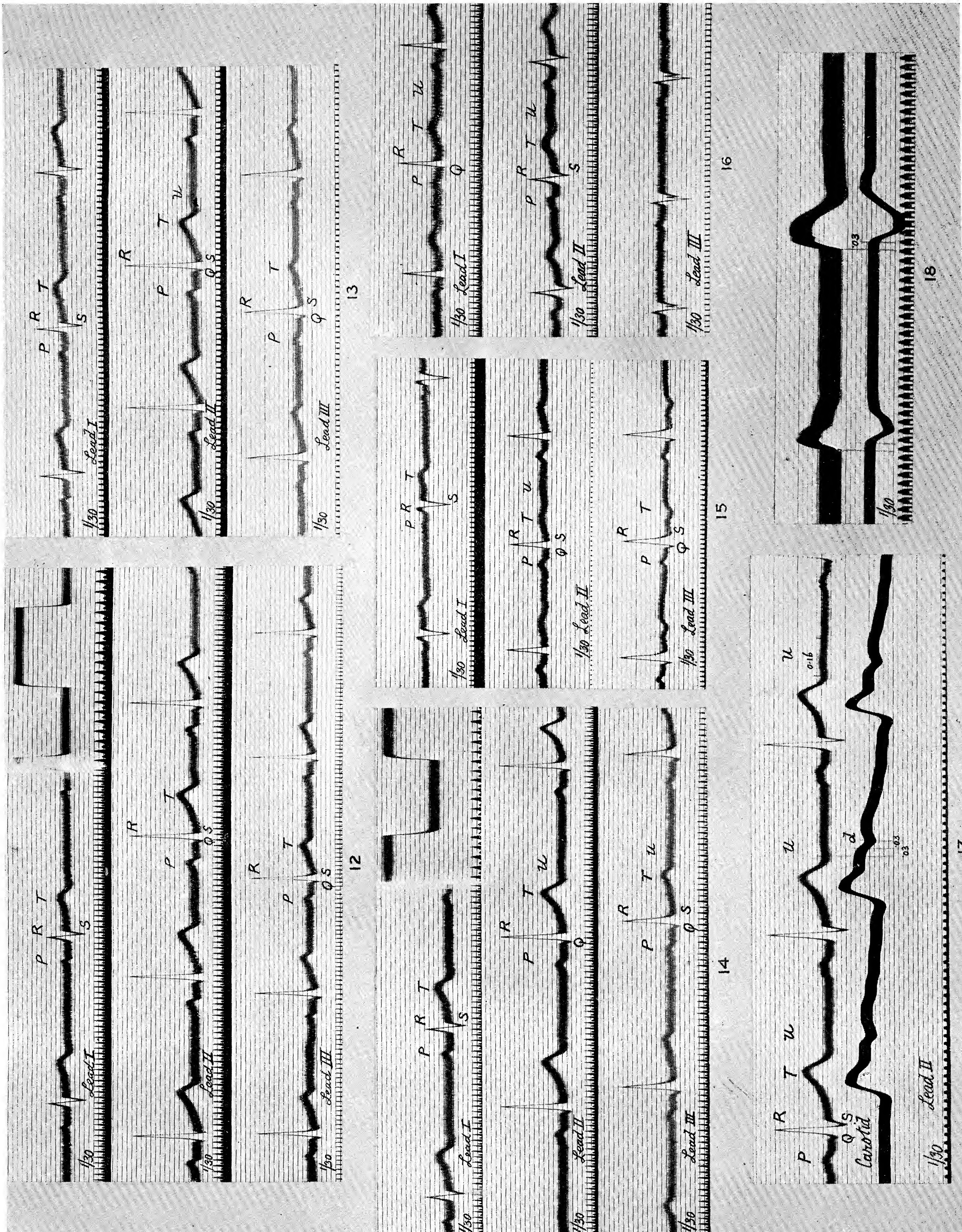
10
11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13
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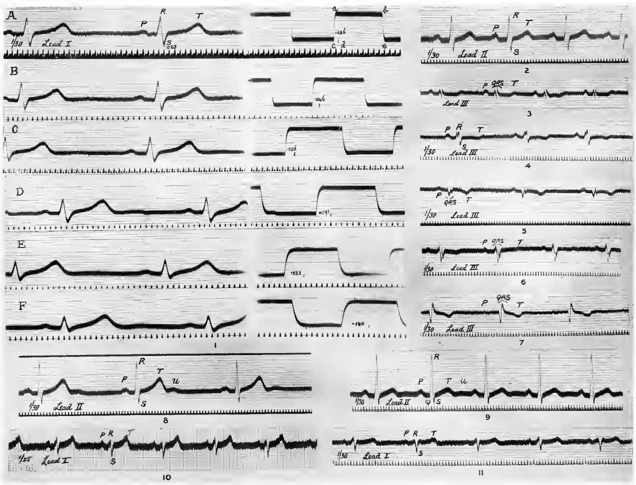
17
18
Lead I
Lead II
Lead III
Carotid
1/30
0·16
·03



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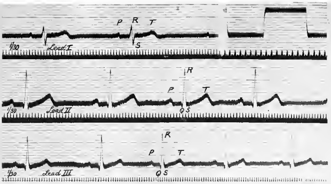

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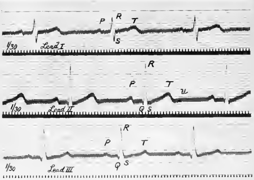

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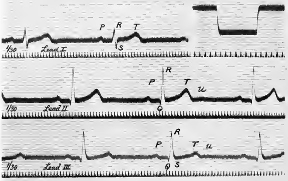

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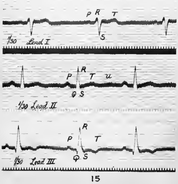

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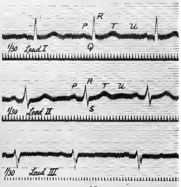

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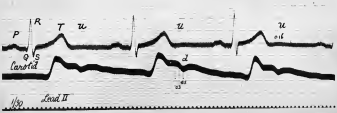

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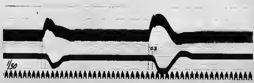

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